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LOADING PATTERNS FOR VENTILATED RAIL AND TRUCK SHIPMENTS OF DRY ONIONS

(A Study of Load Patterns, Cushioning, and Damage)

Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

PREFACE

In recent years, the growth of heavier loading, the use of smaller onions for prepackaging in consumer-size bags by wholesalers, and increased van container shipments of onions to overseas markets have increased the need for better stacking patterns for shipments of dry onions.

This study was made to develop better stacking patterns for shipments of dry onions packed in 50-pound mesh bags. It is one of a series of studies by the Agricultural Research Service to find more efficient, less costly ways of transporting and distributing agricultural and food products.

Growers, shippers, receivers, carriers, and cushioning manufacturers and distributors helped make this study possible by furnishing materials, products, equipment, and facilities for the research. The following members of the Transportation and Facilities Research Division, (TFRD) helped in the field experiments: B. Hunt Ashby, Russell H. Hinds, Jr., Joseph P. Anthony, William F. Goddard, Jr., and Thomas H. Camp. Former members of TFRD who helped in the experiments were David W. Kuenzli, Boris P. Rosanoff (retired), and Kenneth Myers (retired). Dr. Victor C. Beal, Jr., of the Biometrical Services Staff of ARS made the statistical analysys of the data.

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LOADING PATTERNS FOR VENTILATED RAIL AND TRUCK SHIPMENTS OF DRY ONIONS

(A Study of Load Patterns, Cushioning, and Damage)

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SUMMARY

Ventilated loading patterns for bagged onions shipped by rail and motor-truck were developed with dry onions shipped from producing areas in southwest Texas to markets in the Midwest and Northeast. The new patterns have continuous vertical and longitudinal channels between bags in the load, which allow greatly increased rates of air circulation to help remove excess heat and moisture from the product during transport.

In railcar shipments, the ventilated stacking pattern provided approximately 12 percent more air channel space than was available in the conventional log-cabin stacking pattern. Also, the tie-in layers used in the ventilated stacking pattern, to help maintain vertical alinement of the load during transit, did not block or restrict movement of the air through the load.

Data from test shipments by rail showed that onions of good quality and condition can be loaded with 800 bags per car, using either the conventional log-cabin or the new ventilated loading pattern. Difference in the number of damaged bags, the amount of damaged and decayed onions, or the temperatures of loads at destination for the two load patterns studied were not statistically significant. Also, there were no statistically significant differences in the amount of damage according to the number of days from loading to unloading of the shipments. There was, however, a significant increase in product temperature for each additional day's increase in time from loading to unloading. The ventilated loads had less longitudinal shifting than the log-cabin loads, indicating that the ventilated loads were more stable in transit.

A saving of as much as $250 in freight charges for every 800 bags shipped may be gained under incentive freight rates to encourage heavier loading when onions are shipped in 800-bag loads instead of 500-bag loads. Also, a saving of more than $2 in the cost of material used to cushion the load is realized from heavier loading of the onions. Although loss and damage payments increased from an average of $8.05 a car for the lighter loads in 1956 to a high of $13.49 a car in the heavier loads in 1962, the increased

cost of damage was more than offset by increased freight revenue received by the railroads for transporting the heavier loads.

Data from the test shipments by truck indicated that good load ventilation was achieved with the new ventilated load pattern developed for truckloads of onions. Air movement through the channels provided by the stacking pattern caused temperatures throughout the load to change directly with the ambient (outside air) temperature. No damage or decay was found in any of the loads shipped by truck. Measurement of the velocity of air movement in shipments under ventilation showed that the average velocity of air ranged from 210 to 383 feet per minute (f.p.m.) in the channels in the ventilated load and from 213 to 688 f.p.m. over the top of the load at truck speeds of approximately 50 miles per hour (m.p.h.).

Studies to compare the effectiveness of excelsior pads, macerated paper pads, and solid pulp-paper cushioning in rail shipments showed no significant differences in damage to onions. However, temperatures of loads and the amount of decayed onions at destination were significantly higher in loads cushioned with the conventional wood excelsior pads and lowest in loads cushioned with macerated paper pads. The costs of materials to cushion a carload of onions were about the same for the excelsior pads and solid pulp-paper, $2.42 and $2.11, respectively, whereas the cost for macerated paper pads was $3.64.

INTRODUCTION

During the past decade some railroads established lower freight rates for more heavily loaded railcar shipments of some agricultural products. These incentive rates have encouraged heavier loading since shippers can reduce their transport charges per package. During this same period the sizes of the loads shipped in trucks and rail piggybacks also have increased as truck trailers have increased in size and some limitations on highway weights have been raised.

Heavier loading of dry onions has created some problems. Putting more products in the transport vehicles increases the amount of heat to be removed by cooling the loads during transit. Loading to greater heights also increases the overhead weight borne by the containers and the product in the lower layers of the load. Some shippers have hesitated to load products to the maximum permissible limits for fear of greater physical damage and poorer cooling. Dry onions in 50-pound mesh bags are among the products on which load weights increased substantially in response to incentive freight rates.

Also, in recent years, the increase in prepackaging and export has added to the problems of transporting dry onions. The growing popularity of prepackaged products among consumers has increased the demand for smaller onions for prepackaging in consumer-size bags by wholesalers. To meet this demand, onions in southwestern Texas must be harvested earlier in the season, before they reach full maturity. Drying immature onions is more critical than drying mature onions, and the weather during the early season is usually less favorable for curing and drying. Therefore, moisture conditions during

transport are more critical with onions harvested early, which increases the need for load ventilation during transit. A good stacking pattern to permit adequate load ventilation also is important in exporting onions shipped in van containers because the longer distances result in increased time in transit.

This research was undertaken to develop better stacking patterns which would result in more effective cooling of heavier loads in transit. The research also sought to determine the amounts of physical damage to the shipping bags and the onions. Loading patterns for both railcar and truck shipments were studied. This study also evaluated different types of cushioning materials used to protect the product in the bags on the bottom layers in contact with the floors of the vehicles.

FREIGHT CHARGES AND SAVINGS FOR HEAVIER LOADING

Freight rates for different carload minimum rates and savings on freight charges for the heavier loads over the lowest carload minimum weight for shipments of dry onions in 50-pound bags from Laredo, Tex., to Boston, Mass., are given in table 1. The four alternative carload minimum weights ranged from 25,000 to 40,000 pounds, or 500 to 800 50-pound bags per car. Freight charges per carload are based on the actual weight of the loads shipped. Actual carload weights based on the official estimated weight of 50.5 pounds per bag also are shown in table 1.

Savings in freight charges for shipments at the higher minimum weights compared with the 25,000 pounds minimum ranged from 9 percent, or $63.63 per car for the 30,000-pound load to 29 percent, or $258.56 for the 40,000-pound load. Since the freight rates vary with the distance shipments are transported, savings in freight charges for short distances would be smaller than those shown in table 1 and greater to points more distant than Boston.

Although the freight rates per 100 pounds shown in table 1 decrease as the size of loads increases, the heavier loads yielded the railroads more freight revenue per car than the lighter loads. The heaviest load (40,000 pounds) gave the carriers $646.40 per carload of 800 50-pound bags transported at a rate of $1.60 per cwt. compared with $565.60 for a 25,000-pound load of 500 bags at a rate of $2.24 per cwt.

Previous studies have shown that the costs per ton of rail carriers transporting various products are less for heavier loads than for lighter loads.1/ These savings for the rail carriers in transport costs for more heavily loaded shipments derive from more efficient use of transport facilities, equipment, and labor.

1/ Black, W. R. and Breakiron, Philip L. Heavier Loading of Watermelons in Rail Cars and Piggyback Trailers. U.S. Dept. Agri. ARS 52-22, 16 pp. May 1967.

TABLE 1.--Example of rail incentive freight rates and savings on freight charges when dry onions are shipped at various carload minimum weights from Laredo, Tex., to Boston, Mass.

Carload weights (pounds)		No. of bags in load	Freight charges		Freight savings over 25,000 lb. load rate		
Minimum	Actual 1/		Per 100 lb.	Per carload	Per 100 lb.	Per carload	
			Dollars	Dollars	Dollars	Dollars	Percent
25,000	25,250	500	2.24	565.60	--	--	--
30,000	30,300	600	2.03	615.09	0.21	63.63	9
36,000	36,360	720	1.75	636.30	.49	178.16	22
40,000	40,400	800	1.60	646.40	.64	258.56	29

1/ Estimate based on number of bags times official estimated weight of 50.5 pounds per bag.

Source: The Texas Mexico Railway Company, Traffic Department, 1962.

Data in table 2 show the annual loss and damage claims of railroads for onions for the years 1956 through 1963, which covers the period before and during the transition from the lighter to the heavier loads. The average size of shipments from producing areas in Texas during this period ranged from 13 tons, or about 520 bags per car in 1956 to 20 tons, or 800 bags in 1960 and 1961. The average loss and damage per car increased during this period from $8.05 in 1956 to a high of $13.49 in 1962. During this period, however, the increase in the average freight revenue per car received by the railroads for transporting the onions more than offset the additional amount paid by the carriers in loss and damage claims.

TABLE 2.--Payments for loss and damage claims, load weights, and freight revenue for dry onions, 1956-63

Year	Carloads originated 1/	Loss and damage claims of payments 1/		Average load per car 2/	Average freight revenue per car 2/	Net freight revenue per car after payment of loss and damage claims
		Total	Average per car			
	Number	Dollars	Dollars	Tons	Dollars	Dollars
1956	17,882	143,942	8.05	13.0	468.00	459.95
1957	15,656	175,824	11.23	14.0	511.00	499.77
1958	16,179	168,972	10.44	15.0	515.00	504.56
1959	14,910	171,826	10.40	18.0	550.00	539.60
1960	13,738	164,403	11.97	20.0	529.00	517.03
1961	13,327	170,738	12.81	20.0	552.00	539.19
1962	13,307	179,560	13.49	19.8	521.00	507.51
1963	14,128	170,479	12.07	19.8	556.00	543.93

1/ From annual reports of Freight Claim Division, Association of American Railroads. U.S. class I railroads.

2/ From statement TD-1, Carload Waybill Statistics, Oct. 1957, Oct. 1958, May 1959, July 1960, Oct. 1961, Aug. 1962, June 1965, Dec. 1965, Bureau of Economics, Interstate Commerce Commission. Data are for shipments from Southwestern Territory to all points in the U.S. Data for years after 1963 are not available.

CONVENTIONAL STACKING PATTERNS

Railcar Shipments

The log-cabin stacking pattern which was most often used for heavier loading of onions in railcar shipments when this study began is illustrated in figure 1. The stacks are constructed by placing alternate layers of bags lengthwise and crosswise of the railcar.2/

2/ See Appendix for definition of loading terms.

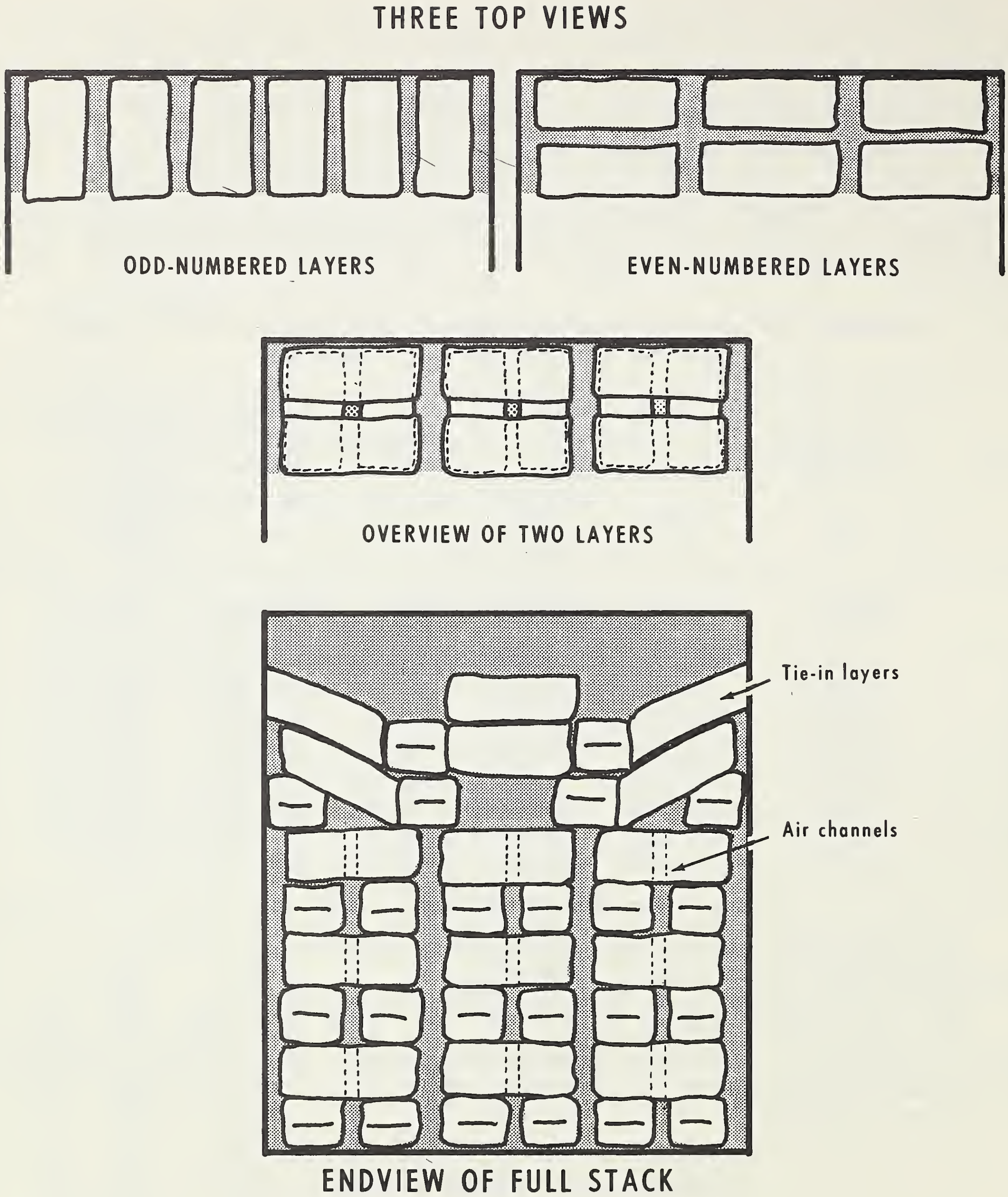

Figure 1.--The conventional log-cabin stacking pattern for railcar shipments of bagged onions. The vertical air channels are blocked by the load stabilizing layers stacked tightly across the top of the load.

Bags in the first layer are placed lengthwise with spaces of about equal width between them. These spaces provide the vertical air channels between the bags in the middle of the load and between the sides of the load and the sidewalls of the car. Bags in the third and fifth layers are placed in the same pattern as those in the first layer. The second layer bags are placed crosswise on top of the lengthwise bags of the first layer, making a so-called log-cabin stacking arrangement. The fourth and sixth layers are identical to the second layer. The last two layers on top are the tie-in layers. Each tie-in layer is made with one bag placed lengthwise over the vertical air channel along each sidewall and two bags are placed lengthwise over each of the two middle vertical air channels resting almost equally on the middle row and adjacent sidewall row. One or two bags in the top layer are placed crosswise and diagonally in the space between the two lengthwise bags adjacent to each sidewall, and one or two bags are placed crosswise over the space between the two center lengthwise bags.

The tie-in layers help stabilize the load crosswise, reducing shifting during transit. However, the tie-in layers block the vertical air channels and restrict the vertical movement of air through the load. It is not uncommon to find the air channels in lower layers blocked at destination because of load shifting and disarrangement of the bags during transit.

Truck-Trailer Shipments

Several different stacking patterns are used for loading onions in truck-trailer shipments. None of the patterns used had air channels through the body of the load. A typical example is shown in figure 2. The bags of onions are so tightly stacked that the incoming air cannot penetrate the load. Since the air coming into the van through the front vent opening is not directed into the body of the load, it follows the path of least resistance and passes over the top of the load and out of the trailer through the ventilation hatches in the rear doors.

Figure 2.--A typical tight-stack pattern for truck shipments of bagged onions with no air circulation through the body of load.

IMPORTANCE OF VENTILATION AND STACKING PATTERNS

A temperature range of 32° to 40° F. is desirable for transporting onions to keep them dormant and prevent sprouting and decay.3/ Temperatures of most onions when loaded for shipment are considerably above this range. The heat load, that is, the amount of heat to be removed from a shipment of onions, is determined by several factors. In addition to the field heat of the product, the heat in the body of the transport vehicle at the time of loading, and heat leakage into the vehicle, the product itself generates heat during transit in its normal respiratory process. For example, the heat of respiration of one ton of onions at 70° is 3,630 B.t.u. for each 24-hour period immediately following harvest. This means that a 40,000-pound load of onions at 70° produces 72,600 B.t.u. of heat per day. As the rate of respiration increases with the temperature, many shipments produce more than this amount of respiratory heat. Although the rate of respiration and the amount of heat generated by the onions decrease somewhat after the first 24-hour post-harvest period, the rates vary directly with the temperature of the product. Bruises, cuts, and skinned areas caused during harvest often become infected with decay, which develops more rapidly as the temperature increases.

Excess heat from all sources should be removed as soon as possible. Ventilation or use of outside air for cooling is the least expensive and most widely used method for doing this since the carriers do not charge for ventilated service.

Product moisture usually is not an important factor in onion shipments from most producing areas of the United States. However, it is important in the Texas-Gulf Coastal Plain and southwestern producing areas where the climate is warm and humid much of the time. Rail shipments from these areas are sometimes loaded to only 75 percent of the capacity of the transport vehicles because of (1) unfavorable effect of prolonged warm, humid conditions on the drying and curing of the onions between harvest and time of shipment, and (2) the fear that conventional loading patterns will not provide sufficient ventilation to aid in the removal of excess heat and moisture from the load during transit.

Also, moisture from condensation may develop when the temperature of the onions is lower than air temperature, particularly if air is humid. Additional moisture is given off by the product in respiration. Excess moisture has two adverse effects: (1) It promotes the development of decay; and (2) part of it is absorbed by the shipping bags. Both of these may help to weaken the shipping bags and detract from their appearance. As the differences in the temperatures of the air and the onions contribute to condensation, they should be held to a minimum. This is best achieved by moving adequate quantities of outside air through the load during transit.

3/ Redit, W. H., and Hamer, A. A. Protection of Rail Shipments of Fruits and Vegetables. U.S. Dept. Agr., Agr. Handb. 195, 108 pp., illus. July 1961.

MODIFIED STACKING PATTERNS TESTED

The extent to how heavy onion shipments may be loaded depends in part on the stacking pattern used. Previous research showed that a good stacking pattern must satisfy the following basic requirements.4/

(1) It must be practical and not too complicated to use.

(2) It must lend itself to rapid stacking.

(3) It must be readily adaptable to the type and size of transport vehicle used.

(4) It must have sufficient density to make maximum use of available load space.

(5) It must have adequate channels to provide air circulation throughout the load.

(6) It must be sufficiently stable to remain intact during transit.

(7) It must help prevent container failure and commodity damage.

(8) It must be acceptable to shipper, receiver, and carrier.

To meet these requirements, a general ventilated design was used in developing the stacking patterns. This design provided many vertical air channels extending from top to bottom of the load in a railcar, and longitudinal channels extending from front to rear of the load in a trailer to allow the air to move freely through the loads.

Pattern for Railcars

The ventilated stacking pattern for loading 50-pound bags of onions in a railcar is illustrated in figure 3. The ventilated pattern is used to build eight stacks of bags, four stacks in each end of the car, extending from each end to the doorway area. Each stack is one and one-half bags in length, consisting of nine layers of nine bags each. A total of 648 bags is loaded in the ventilated stacking pattern. Because of space adjustments and the difficulty of building this stacking pattern from the door, an additional 152 bags are stacked in the conventional log-cabin pattern in the doorway area to complete the 800-bag load.

The ventilated stacks are made by placing alternate layers of bags lengthwise and crosswise of the car. In the first layer, a line of three bags is placed crosswise of the car tightly against the bunker wall, and a line of six bags arranged lengthwise is placed tightly against the first line of bags,

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4/ Hinds, R. H., Jr., and Robertson, J. K. Airflow Loading Patterns for Truck Shipments of Early Potatoes. U.S. Dept. Agr., Market. Res. Rpt. 689, 12 pp., illus. March 1965.

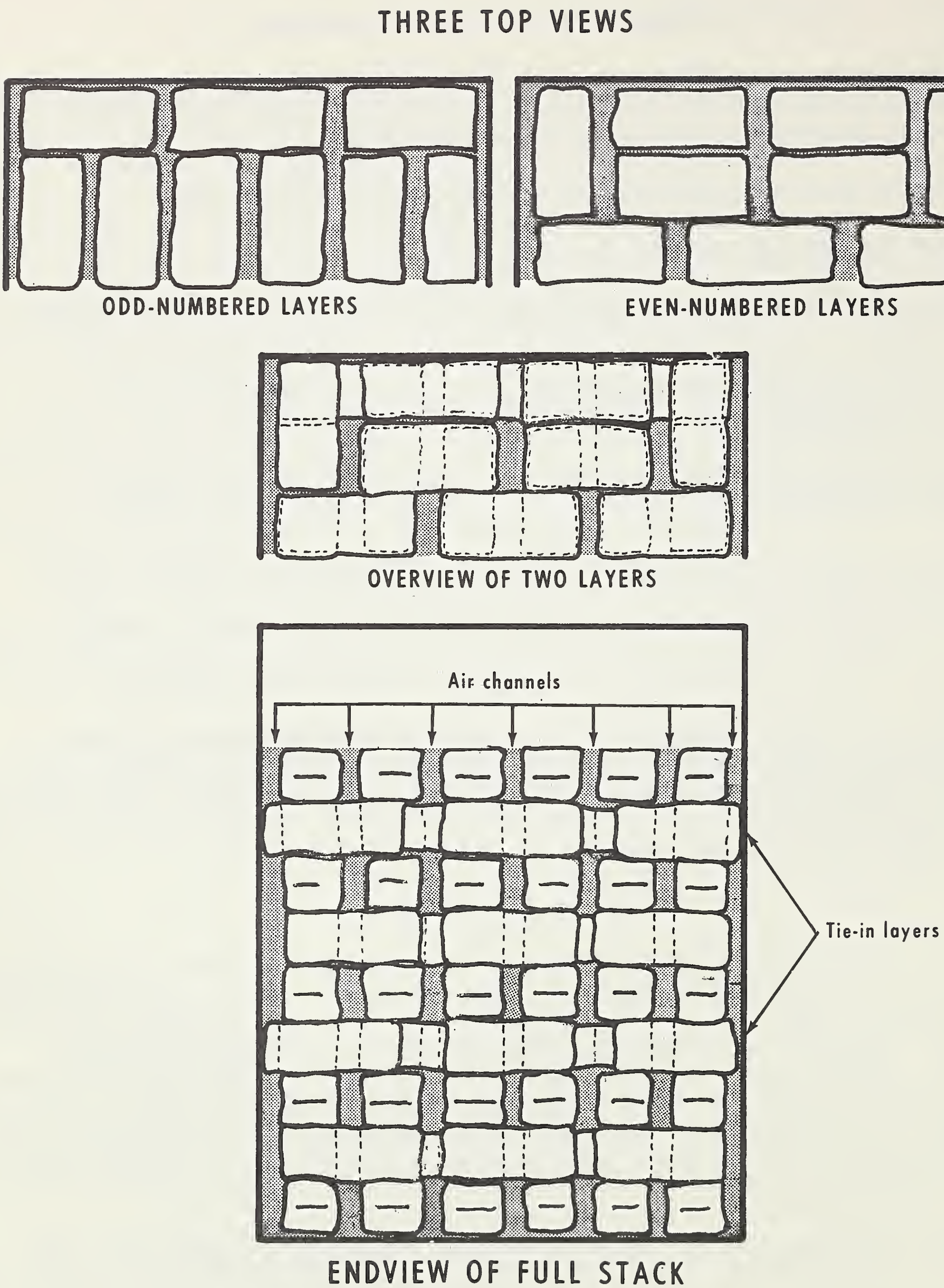


Figure 3.--Ventilated stacking pattern for loading bagged onions in a railcar. Many vertical air channels are provided throughout the load with the center and sidewall rows stabilized to prevent shifting.

with about equal spacing between the bags to form the vertical air channels between them and the bags on the sides of the load and the car sidewalls. The bags in all odd-numbered layers are arranged identically to those in the first layer. The second layer is begun by placing one bag lengthwise of the car against the bunker wall along each side wall. Four bags arranged crosswise are then placed between the two lengthwise bags. Next, a line of three bags crosswise is placed over the remaining exposed bags in the first layer. All second layer bags rest almost equally on the ends of the bags in the first layer. The bags in the fifth layer are arranged in the same way as those in the second layer. The fourth and eighth tie-in layers are made in the same way as the second layer, except that the crosswise bag in each of the sidewall rows is placed tightly against the sidewall of the car.

The tie-in layers help stabilize the load crosswise and reduce crosswise shifting of the load in transit. The design of the ventilated load pattern allows the tie-in layers to be used without blocking or restricting the flow of air through the load.

Pattern for Truck Trailers

To allow the incoming outside air to enter the longitudinal channels in the ventilated stacking pattern in truck-trailers, a special arrangement of bags was used in the front or header stack. This arrangement enables the front stack to serve as a plenum to direct the incoming air to each of the lengthwise channels extending through all subsequent stacks in the load. The same arrangement may be used for refrigerated loads by closing the vent doors and using the blower to reverse the flow of air. The path of air movement through these channels is shown in figure 4 for both ventilated and refrigerated loads.

The ventilated stacking pattern for loading 50-pound bags of onions in a truck is depicted in figure 5. The front stack consists of seven layers and five rows of lengthwise bags. Two wooden car strips are placed crosswise between the second and third, fourth and fifth, and sixth and seventh layers to hold the bags in vertical alinement and thus keep the air channels between the rows open. Strips 3/8 inch thick and 1 1/4 inches wide are cut the desired length to fit the interior width of the vehicle being loaded. The eighth, or capping layer, is made three bags wide and one in length, resting on the bags in the middle and adjacent rows. Additional bags may be placed lengthwise and crosswise in a ninth layer, on top of the capping layer. Subsequent stacks are constructed by alternating the arrangement of the bags in the bottom and cap layers of the header stack. Stacks may consist of more or less than eight layers, depending upon the interior dimensions of the trailer and the distribution of load weight needed to comply with axle-loading requirements. The interior widths of almost all refrigerated and nonrefrigerated trailer vans range mostly from 84 to 89 inches. The ventilated pattern for loading 50-pound bags can be adapted easily to vans of different widths by varying the spacing of the bags across the width of the trailers. The cap layer may be modified to consist of more or less bags so long as the bags are placed tightly together crosswise of the van.

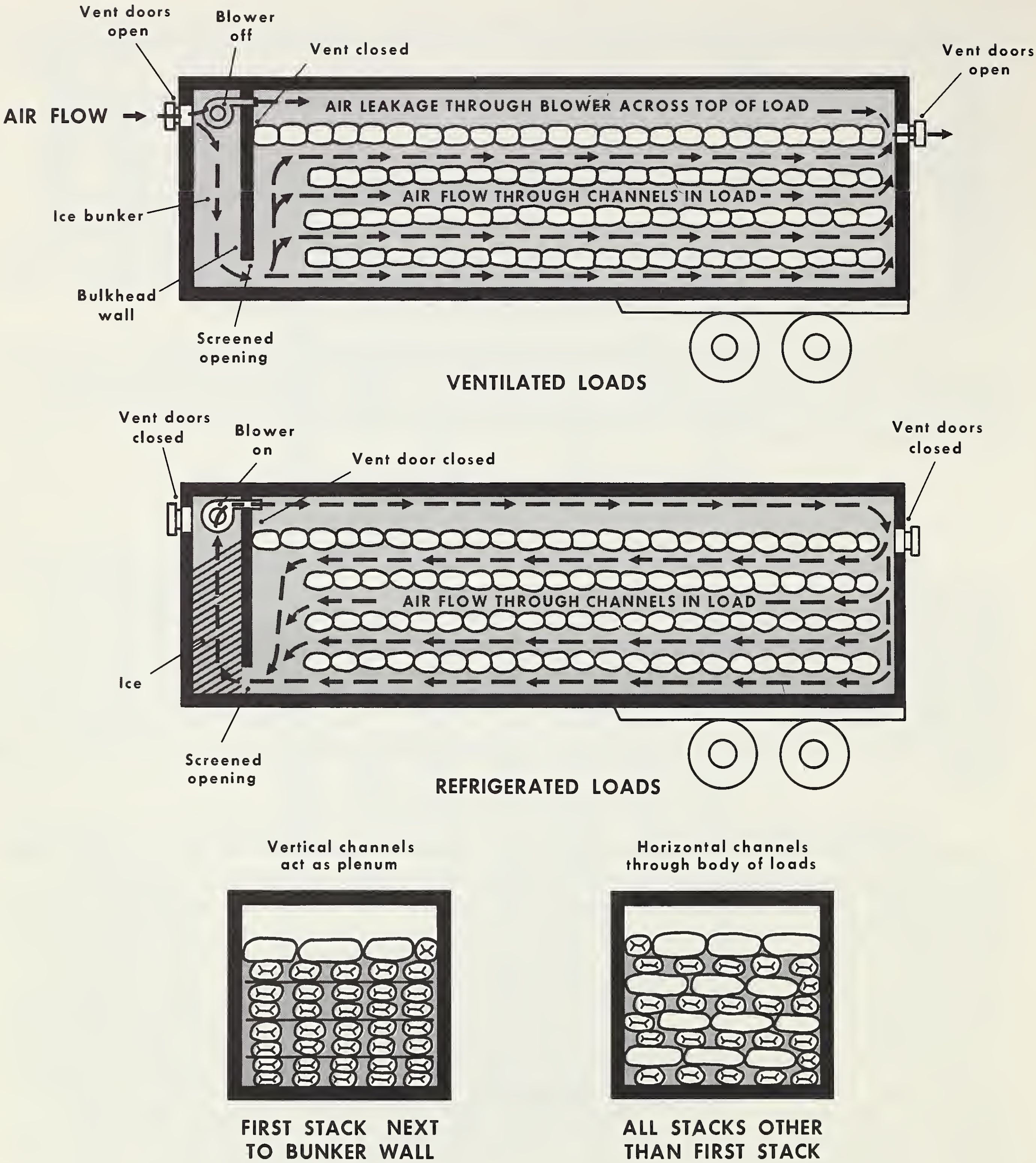


Figure 4.--Air circulation patterns in ventilated loads moving under ventilation or refrigeration.

Figure 5.--Ventilated stacking pattern for trucks. Front or head stack is adjacent bunker. All other stacks are like partial stack in foreground.

METHODOLOGY OF SHIPPING EXPERIMENTS

Stacking Patterns

Railcar Shipments

Transport researchers studied 81 railcar shipments of bagged onions in one shipping season to gather data to compare product damage, decay, and temperatures in the conventional and modified stacking patterns. The conventional log-cabin stacking pattern was used in loading 30 cars and the modified, or ventilated, pattern in 51 cars. All floor layer bags were cushioned. The bags were loaded in the cars eight and nine layers high. The data were analyzed to determine the statistical significance of the differences in product damage. The product temperature and various kinds of damage were analyzed for the effect of the two stacking patterns.5/

The onions were shipped to northern markets from the southwestern producing areas of Texas. All onions were in good condition and had good carrying quality at the time of shipment. Data on condition of the load, physical damage, decay, and temperatures were obtained by inspecting the onions at both shipping points and destinations.

5/ Appropriate statistical techniques were used in this analysis.

Truck-Trailer Shipments

Seven truck-trailer shipments were studied in over-the-highway tests to compare load conditions and temperatures in different load patterns. Five of the shipments were straight ventilated loads and two were shipped as a paired test. Trailers with various inside dimensions were used in the tests. In each test the patterns were adapted to the length and width of the trailers, and the weight of a full payload was properly distributed within the vehicle for compliance with legal axle-loading limitations.

The truck shipments went to southern and southeastern markets from the southwestern producing areas of Texas. All onions were in good condition for transport. Data on condition of the loads and temperatures were obtained by inspecting all the loads at both shipping points and destinations. Temperatures were taken with stick thermometers at various locations throughout the load.

In the paired shipment the ventilated pattern was used in one of the trailers and the tight-stack pattern in the other. The two trailers were loaded simultaneously. They departed at the same time, moved over the same route, and arrived together at the same destination. Temperatures of the load and air were recorded in each shipment during transit to compare temperature variations in the two load patterns.

No statistical analysis was made of the data for the truck shipments because of the limited number of tests.

Air Circulation

Railcar Shipments

The rate of air movement in the vertical circulation channels of the railcar shipments was not determined because of lack of space inside the cars to accommodate the necessary research equipment and personnel. Also, the doors had to be tightly closed to allow the air to circulate.

Truck-Trailer Shipments

The rate of air movement in the longitudinal air channels and over the top of the load was measured for the ventilated stacking pattern in three truck shipments. The rate of air movement could not be measured in the conventional tight-stacking pattern because it had no air channels for the air to move through. These data were obtained with an anemometer while the trailer vents were open and the vehicles were moving at approximately 50 m.p.h.

Load Cushioning

Railcar Shipments

The load and product condition in five cars cushioned with wood excelsior filled pads were compared with those in three cars cushioned with macerated paper filled pads and four cars cushioned with solid molded pulp paper. The data were analyzed statistically to determine the significance of differences

in load stability, number of days from loading to unloading, condition of bags, decayed onions, and onion pulp temperatures.6/

All floor layer bags were cushioned. In the wood excelsior-cushioned shipments, one pad, 10 by 24 by 1/3 inches, was placed on racks on the car floor under each two rows of bags (fig. 6,A). In the macerated paper-cushioned shipments, six pads, 28 by 88 by 1/3 inches, were placed in each end, and three pads, 28 by 48 by 1/3 inches, were placed in the doorway area on floor racks under each two-bag row of onions (fig. 6,B). In the pulp paper-cushioned shipments, six 12-inch-wide strips of solid molded pulp paper, 1/8 inch thick, were placed on floor racks under each two rows of bags (fig. 6,C).

A comparison was made of the costs of and results with wood excelsior, macerated paper, and pulp-paper cushioning in different size loads of onions in railcars. The potential savings in cushioning costs from heavier loading also were compared for the three types of cushioning.

Truck-Trailer Shipments

All the test loads shipped by trucks were cushioned with conventional wood excelsior pads. One pad, 10 by 24 by 1/3 inches, was placed on the trailer floor under each floor-layer bag of onions.

No comparisons were made of the data on load cushioning in the truck shipments because the loads were all about the same size and only one type of cushioning material was used.

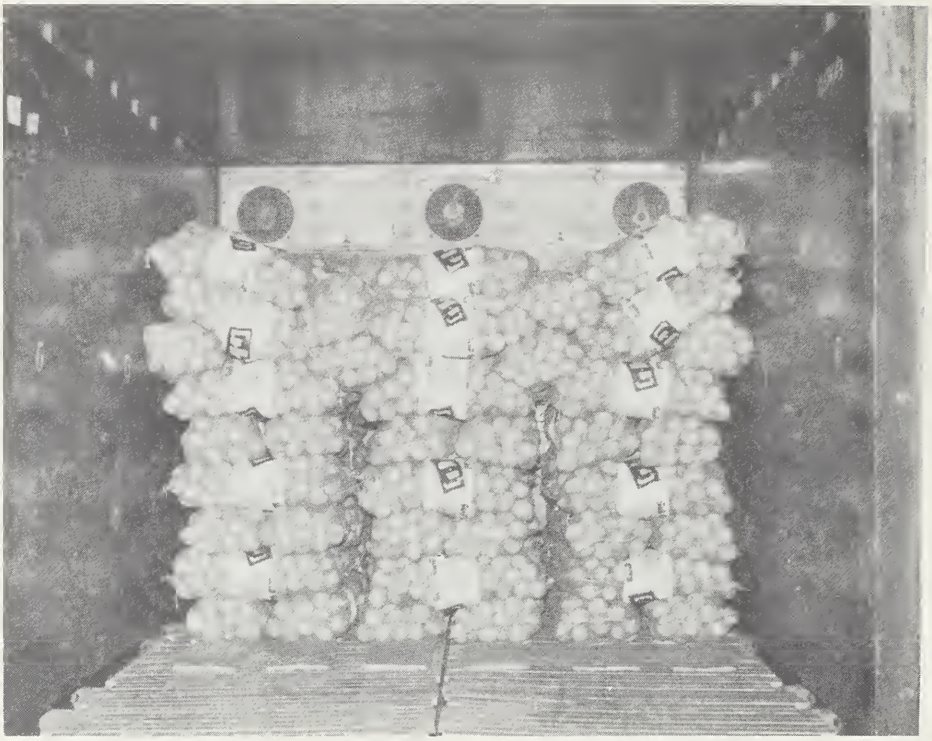
RESULTS

Stacking Patterns

Railcar Shipments

Data on the condition of bags and amount of decay by kind of stacking pattern are shown in table 3. Of total bags damaged in the conventional log-cabin loads, 72.4 percent was repaired and 27.6 percent was damaged beyond repair. Of total damaged bags in the ventilated loads, the comparable percentage were 71.8 and 28.2 percent. Of total onions shipped, the percentage of decayed onions was 0.2 in each of the stacking patterns studied. The differences in damaged bags and decayed onions were not significant between the two stacking patterns.

6/ Several analyses of variance and covariance were run with different degrees of freedom on the different variables because there was no complete set of data for all experimental units in the study.



A. Wood excelsior-filled pads

B. Macerated paper-filled pads

C. Solid molded pulp paper

Figure 6.--Partly loaded railcar shipments of onions showing three types of cushioning on floor racks of car.

The average destination temperatures were 71.1° F. (top of load) and 68.0° (bottom of load) in the log-cabin stacking pattern and 69.5° (top of load) and 67.1° (bottom of load) in the ventilated stacking pattern. These differences in temperature between the two stacking patterns were not statistically significant. However, the effect of the number of days in transit on destination temperature was significant. For each additional day's increase in time from loading to unloading, there was a significant increase in the temperature of the product for both types of stacking patterns.7/

The ventilated loads had less longitudinal shifting than the log-cabin loads. This indicates that the ventilated loads were more stable in transit.

During the study as soon as the loading crews became familiar with the stacking arrangement for the ventilated load pattern, loading proceeded smoothly with no greater effort or time requirements than that needed for conventional loading. At destination, the ventilated loads were unloaded with no more difficulty than the log-cabin loads.

7/ In a regression of temperature on the number of days from loading to unloading there were both significant linear and quadratic effects at the 1-percent level

TABLE 3.--Elapsed time from loading to unloading, container damage, product temperatures, and decay in railcar shipments of onions, by type of load pattern 1/

Type of load pattern	Total shipments studied	Total bags in shipments studied	Average time from loading to unloading 2/	Average product temperatures at destination 2/		Bags damaged			Percentage of total onions shipped that were decayed
				Top of load	Bottom of load	Total	Percentage of total bags: Repaired	Percentage of total bags: Not repaired	
	Number	Number	Days	° F.	° F.	Number	Percent	Percent	Percent
Log-cabin pattern	30	24,000	8.1	71.1	68.0	297	72.4	27.6	0.2
Ventilated pattern	51	40,000	8.3	69.5	67.1	670	71.8	28.2	.2

1/ See appendix table 8 for least squares analysis of variance.

2/ There was no significant difference in destination temperatures between stacking patterns but the effect of days on destination temperatures for both was significant at 1-percent level.

The type of stacking patterns used in this study had no effect on the different variables usually associated with railcar shipments but did affect some of the variables associated with truck trailer shipments.

Truck-Trailer Shipments

Product and air temperatures at origin and destination in five ventilated truck shipments are shown in table 4. These data indicate that good load ventilation was achieved with the ventilated load pattern, and that changes in product temperatures corresponded favorably with outside air temperature during transit. The differences between the average product temperature and the average outside air temperature at origin and destination were only 5.4° and 4.0° F., respectively. The range in product temperature at destination averaged only 3.8° compared with 8.2° at origin. Average product temperature was 6.4° lower at destination than at origin. No damage or decay was found in any of the test loads shipped by truck trailer.

No single shipments by truck trailers were tested using the conventional tight-stacking pattern except to measure the circulation of air through the load at origin. These results are given in the next section of this report under "Air Circulation." Emphasis in this report was placed on developing and testing a ventilated stacking pattern because ventilation throughout the load was not possible in the conventional tight-stacking pattern. Data on product and air temperatures were obtained for the conventional tight-stack pattern using the paired shipment method; that is, one load with the conventional tight-stacking pattern and one load with the ventilated-stacking pattern, moving from and to the same points and over the same route. Only one paired shipment study was possible during the last year that truck tests were made.

Outside air and load temperatures in one tight-stack load and one ventilated load during transit are shown in figure 7. These data show that load temperatures in the ventilated load pattern generally varied directly with the changes in outside air temperatures during transit, indicating good rates of air movement through the load. Load temperatures in the conventional tight-stack load varied less with the changes in outside air temperature.

Although load temperatures corresponded more closely with the outside air temperature in shipments with the ventilated load pattern than in the conventional tight-stacked shipments, cooling of the ventilated loads was not consistent. The effectiveness with which excess heat can be removed depends upon both the amount of air moved through the load and the difference between the air temperature and the product temperature. The lower the temperature of the air moving through the load compared with the product temperature the more effective will be the removal of heat. Using the ventilated load pattern in ventilated shipments will not remove heat during transit when the air is warmer than the product.

Once the loading crews became familiar with the stacking arrangement in the ventilated load pattern, loading and unloading required no more effort or time than that required for the conventional tight-stack load pattern.

TABLE 4.--Product and air temperatures at origin and destination in 5 truck shipments of bagged onions using the ventilated-stacking pattern

Test number	Origin				Destination			
	Product temperature			Average outside air temperature	Product temperature			Average outside air temperature
	Range	Range difference	Average		Range	Range difference	Average	
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
1-------	77-83	6	80.0	90.0	79-84	5	80.0	84.0
2-------	78-84	6	80.2	88.0	79-80	1	79.8	80.0
3-------	82-93	11	86.8	90.0	71-75	4	71.8	70.0
4-------	78-85	7	81.1	89.0	70-75	5	71.9	84.0
5-------	83-94	11	87.7	86.0	78-82	4	79.5	82.0
Average (5 shipments)	---	8.2	83.2	88.6	---	3.8	76.8	80.8

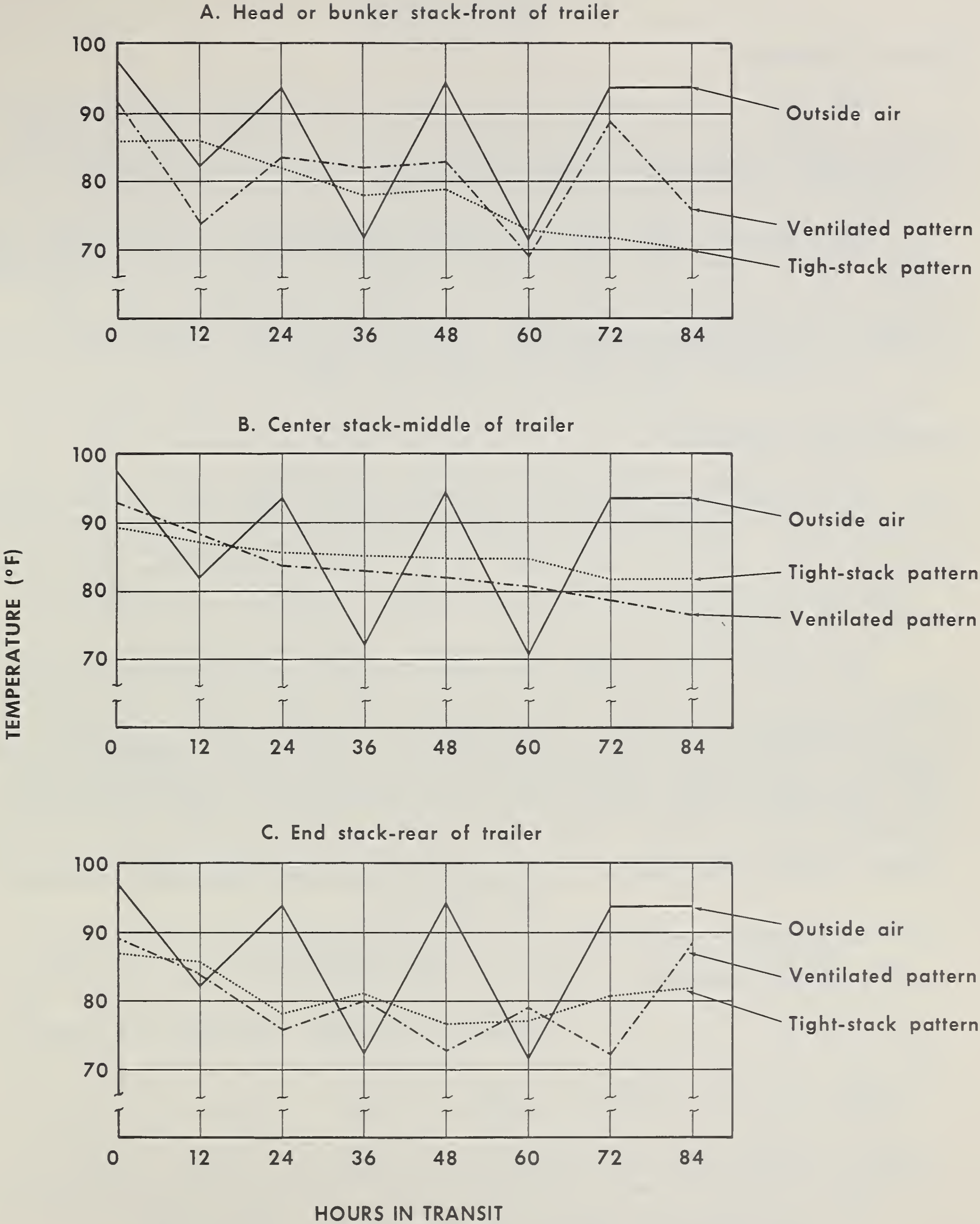


Figure 7.--Outside air and load temperatures in truck shipments of one conventional tight-stacking pattern load and one ventilated load during transit by load location within the vehicles.

Railcar Shipments

The rate of air movement in the vertical circulation channels of the railcar shipments was not measured during transit. However, the ventilated load pattern for rail shipments was designed to allow more air to move through the load than was possible in the conventional log-cabin load pattern.

The ventilated load pattern provided approximately 12 percent more air channel space through the load than was available in the conventional log-cabin pattern. Also, the special arrangement of the tie-in layers in the ventilated load pattern permitted incoming air to move freely through the load. The movement of air through the log-cabin load was restricted by the tie-in layers, which are tightly stacked across the top of the load.

Truck-Trailer Shipments

In the conventional tight-stack load pattern, which has no air circulation channels, the velocity of air movement through the load was inadequate for measurement. Most of the incoming air followed the path of least resistance and passed over the top of the load. In the truck trailers using the ventilated load pattern, the velocity of air movement through all air channels was adequate for measurement.

The data in table 5 show the average velocity of air movement in the longitudinal air channels and over the top of the load for the truck trailer shipments using the ventilated load pattern. Variations in the velocity rates for the different loads resulted from size of channels and irregularities in stacking. The velocity of air through all the longitudinal channels in the three ventilated loads averaged 275 f.p.m., and 412 f.p.m. over the top of the load.

TABLE 5.--Air velocities in 3 truck-trailer shipments with the ventilated load pattern 1/

Location of air velocity reading	Test shipments 1	2	3	Average
	Ft./min.	Ft./min.	Ft./min.	Ft./min.
Average of all longitudinal channels 2/	382	210	275	275
Average across top of load	688	440	213	412

1/ Velocities are given in feet per minute. Truck speed, approximately 50 m.p.h.
2/ Measured at rear of trailers.

Load Cushioning

Railcar Shipments

Data on the condition of the load and amount of damage and decay by type of cushioning are shown in table 6. Onion temperatures and the amount of decayed onions at destination were significantly higher in loads cushioned with conventional wood excelsior pads than in loads cushioned with macerated paper pads.

Load stability was measured by determining the percentage of the air channels open in the loads at destination. This was 65.0 percent in loads cushioned with the conventional wood excelsior pads, 81.7 percent with macerated paper pads, and 60.0 with solid molded pulp sheets. The percentage of bags shipped which were damaged was near 0.7 in loads cushioned with the conventional wood excelsior pads, of which more than 0.4 percent were repaired to good order and 0.2 percent were damaged beyond repair. There were no damaged bags in the loads cushioned with the macerated paper pads or the solid molded pulp sheets. None of the differences in percentages of air channels open or bags damaged was statistically significant.

The percent of bags with decayed onions was 18.3 in loads cushioned with conventional wood excelsior pads, none with macerated paper pads, and 0.1 with solid molded pulp sheets. These differences were statistically significant at the 1-percent level.

Destination temperatures averaged 66.8° F. in loads cushioned with macerated paper pads, 67.7° with solid molded pulp sheets, and 74.2° with the conventional wood excelsior pads. Differences between origin and destination temperatures in loads by type of cushioning were 10.4° with conventional wood excelsior pads, 14.7° with solid molded pulp sheets, and 16.3° with macerated paper pads. The differences in destination onion temperatures between types of cushioning were statistically significant.

Data on the cost of the three types of cushioning, by size of load are given in table 7. A total of 3,525 onion shipments, of 800-bag loads, were shipped by rail from southwestern producing areas of Texas to northern markets in 1964. Had any one of the three types of cushioning studied been used to cushion all of these heavy loads, total savings in the cost of cushioning the 800-bag loads compared with 500-bag loads would be $4,477 for solid pulp paper, $5,111 for excelsior pads, and $7,684 for macerated paper pads. The same amount of material is used to cushion the heavy loads as the light loads. The more expensive the cushioning material, the greater the saving from heavier loading. Total saving of cushioning costs between the most expensive cushioning (macerated paper pads) and the least expensive cushioning (solid pulp paper) would be $5,393 for the 800-bag loads compared with 500-bag loads.

TABLE 6.--Load condition, damage, and decay in railcar shipments of onions loaded in the ventilated pattern, by type of cushioning 1/

Type of cushioning	Shipments	Bags inspected	Load stability as percent of air channels open	Time from loading to unloading	Percentage of total bags in shipment: Damaged	Part empty	Empty	Repaired	Irrepairable	Percentage of total onions decayed 2/	Product temperatures: Origin	Destination	Difference 3/
	Number	Number	Percent	Days	Percent	Percent	Percent	Percent	Percent	Percent	° F.	° F.	° F.
Wood excelsior filled pads---	5	4,000	65.0	8.00	0.68	0	0.04	0.44	0.20	18.30	84.6	74.2	10.4
Macerated paper filled pads---	3	2,400	81.7	7.00	0	0	0	0	0	0	83.1	66.8	16.3
Solid molded pulp sheets---	4	3,200	60.0	12.25	0	0	0	0	0	.13	82.4	67.7	14.7
Overall mean	--	--	67.5	9.20	.28	0	.20	.18	.09	7.7	83.5	70.2	13.3

1/ See appendix table 9 for analysis of covariance.

2/ These differences in decayed onions were significant at 1-percent level.

3/ These differences in temperatures were significant at 5-percent level.

TABLE 7.--Shipper costs of cushioning materials for dry onions transported in railcars from southwestern producing areas of Texas, 1964, and potential savings from heavier loading of railcars 1/

Size of load (bags)	Cars required 2/	Cost of cushioning material 3/						Potential savings from heavier loading 4/					
		Pulp		Excelsior		Paper		Pulp		Excelsior		Paper	
		Per car	Total	Per car	Total	Per car	Total	Per car	Total	Per car	Total	Per car	Total
	No.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.
500	5,640	2.11	11,900.40	2.42	13,648.80	5/ 3.64	20,529.60	--	--	--	--	--	--
600	4,700	2.11	9,917.00	2.42	11,374.00	3.64	17,108.00	0.42	1,974.00	0.48	2,256.00	0.73	3,431.00
700	4,029	2.11	8,501.19	2.42	9,750.18	3.64	14,665.56	.84	3,384.36	.97	3,908.13	1.46	5,882.34
800	3,525	2.11	7,437.75	2.42	8,530.50	3.64	12,831.00	1.27	4,476.75	1.45	5,111.25	2.18	7,684.50

1/ Calculated on the basis of all onions shipped from southwestern Texas, 1964, and the number of cars that would have been required to load the onions at 4 sizes of loads.

2/ 3,525 carloads of 800-bag size were shipped from southwestern Texas in 1964. From Fresh Fruit and Vegetable Shipments Report, U.S. Dept. Agr., Consum. and Market. Serv. C&MS-13, 1964.

3/ Cushioning is required only on the floor of the load, regardless of load height, so the cost per car is the same for all 4 sizes of load. Solid molded pulp paper--1/8-inch x 12-inch x 250-foot rolls; wood-excelsior-filled pads--1/3- x 10- x 24-inch pads; macerated paper-filled pads--1/3- x 28- x 100-inch pads. Costs adjusted for 100-inch long pads instead of the 88-inch pads used in tests.

4/ Per 40,000-pound carload.

5/ Small macerated paper-filled pads comparable in size and cost to wood excelsior-filled pads; 100-inch-long pads came into use after the 1965 shipping season.

Truck-Trailer Shipments

No comparison was made of cost data on load cushioning in the truck shipments since all truck test loads contained about the same number of bags and were cushioned with the conventional wood excelsior pads.

CONCLUSIONS AND RECOMMENDATIONS

Shippers benefit from lower charges for rail freight for heavier loaded shipments of onions by the customary 8-layers-high log-cabin load pattern or the new 9-layers-high ventilated load pattern. Onions of good carrying quality and condition may be safely loaded 800 bags to a car, by either load pattern, without an increase in onion damage or decay sufficient to offset savings in freight charges. Differences in the number of damaged bags and the amount of damaged and decayed onions were not statistically significant.

Truck trailer shipping tests of bagged onions showed that air circulation can be increased in all parts of the load by using the ventilated stacking pattern tested in this study. The new ventilated pattern provides increased flow and more uniform distribution of air along the perimeter and through the center of the load to facilitate the removal of heat and moisture from the onions during transit.

The cost of cushioning material also is reduced by heavier loading of both railcar and truck trailer shipments. The same amount of cushioning material is used for all load heights; therefore, the cost of material per bag of onions is lower for heavier loads.

The new ventilated stacking patterns developed and tested in this study increased circulation of air through the load. Therefore, better environmental conditions are possible during transit for domestic shipments of less mature, moist onions harvested and sacked for shipment during moist weather. Increased air circulation through the load should be of particular importance to exporters shipping onions to overseas markets in either refrigerated or ventilated van containers.

Shippers, receivers, and carriers will obtain maximum benefits from shipping heavier loads of onions in ventilated railcars and truck trailers by following these recommendations:

1. The onions shipped in heavier loads should have good carrying quality and be in good condition.

2. All onion shipments should have adequate cushioning material on the floors of railcars and trailers.

3. The onions should be transported to destination as quickly and carefully as possible.

4. Both railcar loads and truck trailer loads should be unloaded as soon as possible upon arrival at destination.

5. Onions which have not been adequately dried before shipment and onions being shipped long distances should be loaded in one of the ventilated stacking patterns tested.

APPENDIX

Definitions of Loading Terms

Layer.--A course or stratum of the load, parallel to the floor of the vehicle, one bag in height.

First layer.--The layer of bags resting on the floor or floor racks of the vehicle.

Second layer.--The second layer counting up from the floor of the vehicle.

Tie-in layer.--A layer of bags extending from one side of the vehicle to the other, placed tightly together and against the sidewalls, for the purpose of preventing the rows of bags in other layers from shifting crosswise of the vehicle.

Lengthwise.--Arrangement of bags in a vehicle with the ends of the bags towards the ends of the vehicle.

Crosswise.--Arrangement of bags in a vehicle with the ends of the bags towards the sides of the vehicle.

Row.--Pile of bags extending lengthwise of a vehicle, parallel to the sides of the vehicle, and one bag in width.

Stack.--Pile of bags extending from one side of a vehicle to the other, parallel to the end of the vehicle. A stack may vary from 1 to 1 1/2 bags in length, depending upon the stacking pattern used.

TABLE 8.--Least squares analysis of variance for 8 variables in railcar shipments of bagged onions, by source of variation, 1964

Source of variance	Mean square for error and F values for tests of significance for the different variables 1/								
	Degrees of freedom	Total damaged bags	Total bags repaired	Total bags with part of contents missing	Total bags seriously damaged	Total bags with all contents missing	Decay	Product temperature: Top of layer	Product temperature: Bottom of layer
Stacking pattern 2/	1	0.556	0.572	1.295	0.400	1.086	0.432	0.625	0.191
Linear regression 2/	1	.108	.129	.776	.662	.287	.277	3/ 22.300	3/ 24.877
Quadratic regression 2/	1	.022	.001	.659	1.288	.315	.016	3/ 17.173	3/ 19.003
Error 4/	77	7.355	4.173	.298	.689	.005	3.90	81.67	84.11

1/ $Y_i^* = H_i + b_1 x_i + b_2 x_i^2$

Where:

Y_i = the experimental response of the i_{th} group.

H_i = effect of the i_{th} type of load.

b_1 = linear regression of experimental response on days.

b_2 = quadratic regression of experimental response on days.

$x_i = (X_i - \bar{X})$ where X_i refers to the number of days car i is en route, and $\bar{X}$ refers to the average number of days that all cars are en route.

2/ F value--ratio of mean square to error mean square.

3/ Significant at 1-percent level.

4/ Error mean square.

*Y_i refers to experimental response as percent damage, decay, or temperature.

TABLE 9.--Analysis of covariance in railcar shipments of bagged onions by source of variance, 1963

Source of variance	Degrees of freedom	F values for sources of variation mean square for error 1/
Damage with load stability as covariate:		
Treatments	2	1.04
Regression on load stability	1	<1
Error, mean square	11	314.5
Decay with days as covariate:		
Treatments	2	2/ 12.06
Regression on days to unload	1	1.69
Error, mean square	12	58.1
Decay with destination temperature as covariate:		
Treatments	2	2/ 8.22
Regression on destination temperature	1	6.44
Error, mean square	10	39.0
Decay with load stability as covariate:		
Treatments	1	2/ 8.10
Regression on load stability	1	<1
Error, mean square	11	48.9
Destination temperature with origin temperature as covariate:		
Treatments	1	3/ 7.44
Regression on origin temperature	1	<1
Error, mean square	7	7.6

1/ $Y_i = H_i + b_1 x_i$

Where:

Y_i = the experimental response of the i_{th} group.

H_i = effect of the i_{th} type of load.

b = regression of damage, decay or temperature change on load stability, days or temperature.

$x_i = (X_i - \bar{X})$ where X_i refers to the number of days car i is en route and $\bar{X}$ refers to the average number of days that all cars are en route or to load stability or to temperature.

2/ Significant at 1-percent level.

3/ Significant at 5-percent level.

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